DUAL BEAM PARALLEL PLATE SLOT ANTENNA

Manuel Sierra Castañer , Manuel Sierra Pérez , José Luis Fernández Jambrina , María Vera Isasa Oscar Moreno Gimenez

INTRODUCTION

We show here the design of a dual beam linearly polarised flat antenna. The main goal is getting a low cost antenna to use for the simultaneous reception of Hispasat and Astra satellite emissions in the 12 GHz band. The gain needed for the antenna is around 30dBi. A rectangular array of slots in the upper side of a parallel plate wave guide form the main antenna structure. The guide is excited with two feeding structures from both sides of the antenna.

Parallel plate slot antennas have been widely studied by Ando and Hirokawa [1], from 12 GHz to Millimeter Wave frequencies. The main modifications we introduce here is the possibility of two simultaneous beams. We also modify the feeding network, the design procedure and the materials used to build of the radiation surface.

The feeding networks are two microstrip circuits designed with Ensemble v.5.1.® They are placed at both sides of the antenna. Each of them generates a beam that radiates 25º deviated from the broadside in one of the main planes. The beam steering along the main plane can be controlled with the design of the feeding network. For this prototype we don't modify the radiation angle in the second plane, but it will be considered for next work.

PARALLEL PLATE WAVE-GUIDE

The antenna main structure is made with two metallic plates, 7mm apart, and filled by two kind of dielectric materials: a low density foam dielectric and n epoxy fibre glass. The ground plane is a 05mm thick aluminium and the upper plate is a copper metalled, low thickness fiber-glass sheet. The upper plate will support the slots printed antenna, while the ground plane supports the printed feeding structure at both sides of the antenna. Fig. 1 shows a schematic section if the antenna structure.

The shape of the antenna is rectangular, with the slots printed in the upper plate, all of them parallel to the others to give linear polarisation in both beams. To get a plane feeding wave inside the guide a line of resonant poles were placed in the side of the antenna and fed with equal amplitude and phase. Both waves, one coming from the left and the other coming from the right, generate field in the slots to radiate in two different directions, allowing a dual beam antenna. Fig. 2 shows a schematic drawing of the antenna.

The position of the antenna is calculated after imposing two conditions: first the slots are placed normal to the direction of the both horizontal polarisation (to get the horizontal polarisation) at the reception point (Madrid), and second the same radiation surface must be used for both beams, by only modifying the feeding circuit. The positions of Astra, Hispasat and Madrid are showed in table1. The two pointing angles, considering the coordinate system of the plane of the antenna and the vector normal to it, are showed in table 2.

Table 1: Latitude and Longitude of the Satellites and Reception Point

	Latitude	Longitude
Hispasat	0	30º W
Astra	0	19.2º E
Madrid	40.3º N	3.4º W

Chart 2: Pointing angles from the antenna to both Satellites

	Theta	Phi
Hispasat	27.7º	83.4º
Astra	27.3º	92.5º

The pointing angle of the antenna, in the direction normal to the slots, is 27.3° for both beams. This angle imposes the separation of the radiation elements in the direction normal to the slots. Other Specifications for this first prototype are: gain for each beam 30 dBi and central frequency 12 GHz.

FEEDING STRUCTURE AND PLANE WAVE EXCITATION

The feeding network has been printed in a 0.25mm thick teflon-glass substrate. It is based on an array of resonant pins fed by a microstrip line to get an homogeneous field in a plane wave inside the guide. In the design of resonant pin length it is necessary to take into account the influence of the two ground planes and the coupling between them. The input impedance of each pin has been adjusted to 100ohm, that is the same impedance value of the microstrip transmission line used to feed them. The distance between pins is around one wavelength measured in the microstrip line, to keep the phase constant in the series feeding structure. The number of pins is 12 along the 300mm length of the antenna. The feeding structure is formed by a parallel distribution to four lines plus a series feeding of three element subarrays.

The amplitude of each one is optimized to get uniform amplitude inside the guide. The phase of each patch is optimized to get the desired angle for each beam (Phi in table 2). Fig. 3 shows the relative amplitude of each pin and the field amplitude obtained inside parallel plate waveguide.

SLOT COLUMNS

The radiating structure is formed by columns of slots printed in the upper plate. Each column acts as a full radiating element in a travelling wave antenna, and we can associate to it a radiated power and a set of transmission and reflection parameters in the waveguide. The radiated power depends on the slot length, that is constant for all the slots in a column, and we can adjust this length to control the excitation along the antenna aperture. But as the radiated power is increased, the reflection also increases, giving a reflected wave that creates a large.

To reduce the reflection from the slots, the radiation element consists on three slots. The central one is longer than the side ones and it is the one that radiates the power. The other two slots are much shorter than resonance length and reduce the reflection of the main slot. The structure to be analysed is showed in figure 4. There are two regions, the half free space and the waveguide. For the half free space we consider periodicity in both directions, to consider the coupling among all the slots. For the inner waveguide we consider the periodicity in one direction (the direction parallel to the slots). The upper plate is considered zero thickness. The integral system of equations (1) is solved by the Galerkin Method of Moments, and the equivalent magnetic currents on each of the three slots are obtained.

For j=1:3,
$$\vec{H}in + \sum_i \vec{M}_i(\vec{r}_i) \otimes \overline{\overline{G}}^{WG}(\vec{r}_j / \vec{r}_i) = -\sum_i \vec{M}_i(\vec{r}_i) \otimes \overline{\overline{G}}^{HS}(\vec{r}_j / \vec{r}_i) \tag{1}$$

The base functions are complete sinusoidal ones for each slot (2). One base function is enough for solving the system [2].

$$\vec{m}_i(\vec{r}) = \frac{1}{w} sin \frac{k\pi}{l}\left(z + \frac{l}{2}\right)\hat{z} \qquad k = 1 \cdots N \tag{2}$$

For the analysis of the inner waveguide hybrid TE^y and TM^y modes are used. For a two dielectrics geometry the wavenumber for each direction are [3]:

TE^y modes:

$$\frac{k_{y1}}{\mu_1} \cdot cot\left[k_{y1} \cdot h_1\right] = -\frac{k_{y2}}{\mu_2} \cdot cot\left[k_{y2} \cdot h_2\right] \tag{3}$$

TM^y modes:

$$\frac{k_{y1}}{\varepsilon_1} \cdot tan\left[k_{y1} \cdot h_1\right] = -\frac{k_{y2}}{\varepsilon_2} \cdot tan\left[k_{y2} \cdot h_2\right] \tag{4}$$

These expresions are completed with the wavenumber in a periodic structure,

$$
\begin{aligned}
&k_x^{\,2} + k_{y_1}^{\,2} + k_z^{\,2} = \omega^2 \mu_1 \varepsilon_1 \\
&k_x^{\,2} + k_{y_2}^{\,2} + k_z^{\,2} = \omega^2 \mu_2 \varepsilon_2 \\
&kx = k_0 \cdot \left(\frac{2m\pi}{a} + \sin\theta \cos\phi \right)
\end{aligned}
\tag{5}
$$

The length of the reflection cancelling slots is calculated to minimize the reflection coefficient. Then the radiated power is calculated for each structure. This power depends mainly on the length of the slots, and also on the distance between slots. Figure 5 shows the length of side slots as a function of the main slot, and figure 6 shows the radiated power (% over incident power) as a function of the length of main slot.

DESIGN OF THE RADIATION SURFACE

The length of each slot in one line is calculated to have uniform amplitude in the antenna. Obviously it is not possible to get uniform amplitude for both beams, so a process calculates the length of the central slot of each radiation element to optimize that value. Environ 70% of the power is radiated by the first half of the antenna and 30% of the power for the second half.

After that the phase of each slot is calculated to get uniform phase for each beam. The same problem appears. For the first beam the position of the first half is optimized, for the second beam the position of the second half.

CONCLUSIONS

A design method for the synthesis of double beam linearly polarized parallel plate antenna has been presented. This work pretends to study the possibilities of this kind of antenna for getting two independent beams. Measurements will be showed at the conference. This work is included into the project FEDER nº1-FD97-0276-C02-02. We want to thank the financial supporting from FEDER.

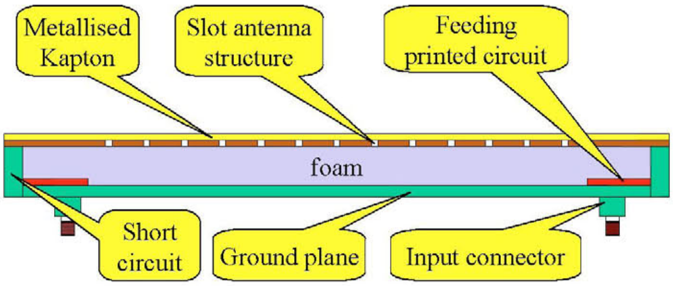

Fig. 1. Scheme of the transmission line section.

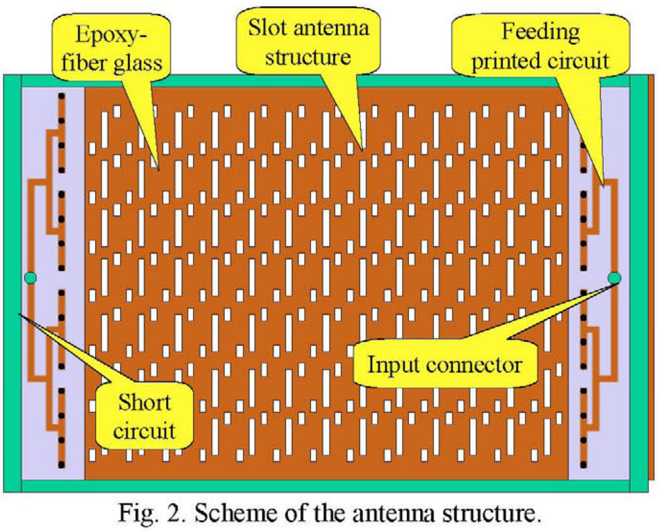

Fig. 2. Scheme of the antenna structure.

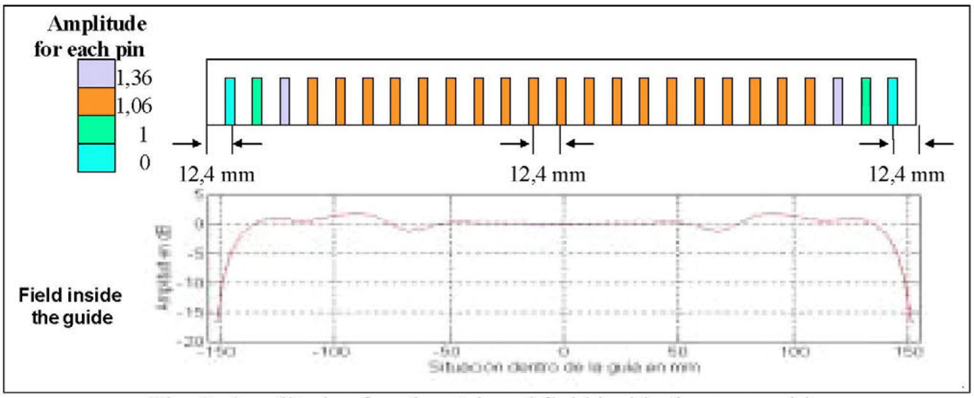

Fig. 3. Amplitude of each patch and field inside the waveguide

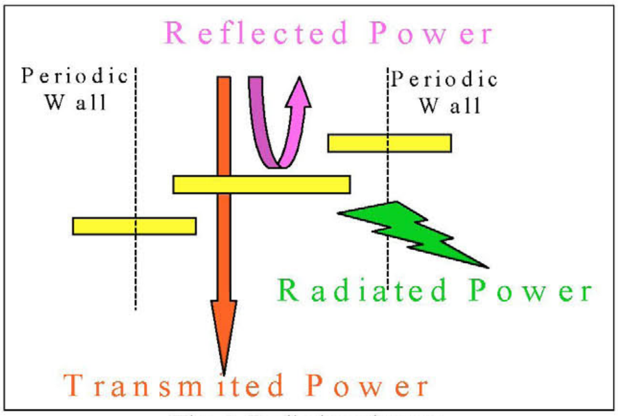

Fig. 4. Radiating element

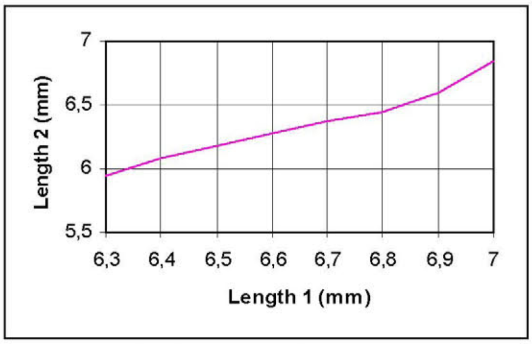

Fig. 5: Length of side slots

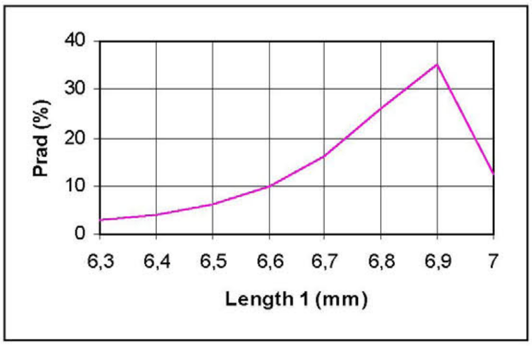

Fig. 6: Radiated Power

References

[1] J. Hirokawa, M. Ando. "Single-Layer Feed Waveguide Consisting of Posts for Plane TEM Wave Excitation in Parallel Plates". IEEE Trans. on Antennas and Propagation. Vol. 45, No.5 Mayo 1998, pp. 625-630.

[2] Jiro Hirokawa, Makoto Ando, N. Goto. "Analysis of Slot Coupling in a Radial Line Slot Antenna for DBS reception" IEE Proceedings, Vol 137, Pt. H, No.5, October 1990. Pag. 249-254

[3] C.A. Balanis "Advanced Engineering Electromagnetics", John Wiley & Sons", Nueva York, 1989.